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ABSTRACT

This paper reports on research carried out in Sweden on concept formation as related to science education. Particular emphasis is given to the aquisition of the concepts of proportionality and density by tenth-grade students. Comparisons were made of the student's everyday thoughts about density and their ability to understand the Cartesian Diver demonstration. (BB)

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CONCEPT FORMATION IN MATHEMATICS AND THE NATURAL SCIENCES, THE INTEGRATED UPPER SECONDARY SCHOOL (4)

A RESEARCH APPROACH INTO SCIENCE EDUCATION AT GÖTEBORG

Paper presented at the Joint ICMI/ICPE/CTS/ UNESCO/IDM-conference on 'Cooperation between Science Teachers and Mathematics Teachers', September 17 - 23, 1978, Institut für Didaktik der Mathematik, Bielefeld, FRG.

Leif Lybeck

Appendix:'Analysis of Condition for Cooperation and Strategies for Innovation related to the Cognitive Domain'
(Working Group Members: Bent Christiansen, Peter Fensham, Karl-Wolf Hoffmann, Leif Lybeck and Hans-Georg Steiner)

No 71 October 1978

INSTITUTE OF EDUCATION, UNIVERSITY OF GÖTEBORG
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FORWORD

We intend to explain what the capital letter abbreviations in the Joint ICMI/ICPE/CTS/UNESCO/IDM-conference represent.

The International Council of Scientific Unions (ICSU) has a Committee on the Teaching of Science (CTS) which is very active in organising international discussions on the teaching of all the sciences. One of the members of ICSU is the International Mathematics Union (IMU). However, perhaps because of the prominent place of mathematical instruction through-out educational curricula, IMU's International Commission on Mathematical Instruction (ICMI) also pursues its own very active programme, e.g. a large International Congress of Mathematical Education every four years: the 1972 Congress in Exeter and the 1976 Congress in Karlsruhe.

The International Commission on Physics Education (ICPE) is one of the 16 Commissions of the International Union of Pure and Applied Physics (IUPAP), and its purpose is to promote activities aimed at encouraging the learning of physics at all levels of education. The Commission was formed in 1960 as the outcome of the first major international conference on physics education, held that year in Paris. Since then ICPE has sponsored a total of nine international conferences on various aspects of physics education. (International Newsletter on Physics Education, ICPE, No 4, August 1978, p 2.)

The 1972 International Congress of Mathematical Education (Exeter) included a Working Group 'Links with other Subjects at Secondary Level'. This emphasized skills in mathematical modelling of scientific problems as one of the important groups of mathematical skills to be communicated in secondary school and argued that the necessary material can be prepared best through cooperation between science teachers and mathematics teachers. And now, a collaborative programme was established between CTS and ICMI and UNESCO (The United Nations Educational Scientific and Cultural Organisation) aimed at preparing a conference at Bielefeld, West Germany, in September 1978 and at bringing about the publication for a mass market of a book

on 'Cooperation between Science Teachers and Mathematics Teachers'. Through cooperation with IDM (Institut für Didaktik der Mathematik, Universität Bielefeld) the Joint ICMI/CTS/ICPE/UNESCO/IDM-conference on 'Cooperation between Science Teachers and Mathematics Teachers' was planned and held at Bielefeld, West Germany, September 17 - 23, 1978. About 40 researchers from countries outside West Germany were invited. 10 researchers from Bielefeld and 10 others participated in the conference.

Concerning the programme and its content, two major components were formulated by Hans-Georg Steiner, Vice-President of ICMI and professor at IDM:

(1) Development of material and teaching models which help to bridge the gaps between mathematics and the sciences as school subjects. The material may contain elaborated examples from the content point of view, methodological considerations on the utilization of mathematics in the sciences, mathematical model building, outlines of curricula with emphasis on systematic cross-reference between mathematics and the sciences etx.

The teaching models may vary from traditional class-rrom and course teaching, the teaching of small modules etc to project work; from single teacher class-rooms to team-teaching.

(2) Research and studies related to the various organisational, educational, sociological and psychological factors and conditions which determine the present situation and which have to be reflected when designing innovative strategies, e. g.

- Effects of different philosophies and methodologies, related to mathematics and the sciences, on the school curricula. Analysis, in particular, from the perspective of the history and the sociology of sciences and school-subjects.
- Effects of teacher-training (socialization of teachers; acquired knowledge and understanding of their subject, acquired educational theory and prctise etc.) and the professional situation of teachers.
- Cognitive differences between mathematics and the sciences in their thinking and working methods. Individual and developmental aspects of these differences; learning difficulties among pupils; problems of motivation etc.
- Conditions specifically related to developing countries.

At the conference, five Working Groups were formed:

Group A 'Science Applications and Model Building as Part of the School Mathematical Curriculum'

Group B 'Use of Mathematics in the Physics Education'

Group C 'Use of Mathematics in the Biology Class-room'

Group D 'Use of Mathematics in the Chemistry Class-room'

The four Working Groups mentioned were mainly engaged in theme (1) activity and the Working Group E in theme (2) activity as formulated above. The Group E was divided in four subgroups:

Group E1 'Epistemological conditions'

Group E2 'Cognitive conditions'

Group E3 'Socio-psychological aspects of cooperation'

Group E4 'Education; school organisation, etc.'

In this report No 71, I enclose the paper worked out by the Group E2 of the Group E. The paper is of special interest to our research approach to Mathematics and Science Education as elaborated in the BMN-project, The Institute of Education, University of Göteborg.

I presented another paper at the conference on 'Studies of Mathematics in Science Lesson in Göteborg'. It is published as report No 72 in this series.

Mölndal October 1978.

Leif Lybeck

CONCEPT FORMATION IN MATHEMATICS AND THE NATURAL SCIENCES, THE INTEGRATED UPPER SECONDARY SCHOOL
is a translation from the Swedish name
BEGREPPSBILDNING INOM MATEMATIK OCH NATURVETENSKAPLIGA ÄMNEN, GYMNASIESKOLAN (the BMN-project).
The BMN-project is sponsored by the National Swedish Board of Education during the fiscal years 1975/79.

A RESEARCH APPROACH INTO SCIENCE EDUCATION AT GÖTEBORG [0)]

In order to convey some ideas of our research approach in the RMN-project[1)], it is necessary to mention some features of its intellectual environment. Our daily work is an integrated part of the research activities of the so-called INOM group[2)].

The INOM group

A question of unifying interest in the group is that people's conception of direct experiences of various phenomena of information in spoken or written form, are qualitatively different. The starting point is that the way in which people understand the world around us, constitutes both prerequisites for and effects of learning. Using certain areas of subject matter the members of the group have studied the individuals' thought content, as it is manifested in students' answers during interviews carried out by the researchers. They have been able to describe qualitatively different conceptions of, for instance, a principle. Such research results are issues for subject methodology. The problem is how to teach a concept or a principle in an appropriate way to a group of students. The purpose of the descriptions of qualitative differences, which constitute research results, is to make the teacher sensitive to the various ways in which students think in relation to different principles, ideas etc. The aim of this is to provide the teacher with knowledge so that he can judge what his students have not grasped (Lybeck, Marton and Säljö, 1976). The core members of the group

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0) A Shorter version is to be published in the European Journal of Science Education, November 1978.

1) The project is sponsored by the National Swedish Board of Education. BMN is short for the Swedish name and can be translated as 'Concept Formation in Mathematics and the Natural Sciences'.

2) A collective name for several research projects at the Institute of Education, The University of Göteborg. INOM is a Swedish abbreviation for Learning and Conceptions of the World Around Us. The scientific leader is professor Ference Marton.

have summed up their earlier results (Marton, Dahlgren, Svensson and Säljö, 1977). These studies were concentrated on higher education and adult teaching in Education (Marton and Säljö, 1976; Svensson 1978) and Economics (Marton and Dahlgren 1978). Marton (1976) has discussed some theoretical and methodological issues on non-verbatim learning related to the studies.

During the four last years the group has widened its research interests. A project has been launched which deals with adults' conception of measures taken by the community in order to support individuals. Likewise, a study of the adults' conception of power and the wielding of power in relation to an experienced political event, is being undertaken. A third study deals with adults' comprehension of statistical information (the concepts of mean value and correlation). Another sign of the increased research activities of the INOM-group is the BMN-project.

The activity of the BMN-project[3] is in line with experimental activity on research training in subject methodology at our Institute of Education. At present, this leads to the Swedish degree of Doctor of Philosophy in Education with subject matter orientation in Mathematics [4] or Physics. This new orientation has been discussed by Härnqvist (1974).

We have outlined som features of the intellectual environment of the BMN-project. Against this background, we would like to discuss objectives, methods and types of results obtained so far. We shall first present a conceptual distinction from Theory of Science[5] in order to clarify a point in our research approach.

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3) It should be mentioned that our professional training is in Mathematics and a number of the Natural Sciences and that we have been teaching at school level and at university level, e.g. teacher training college.

4) The research assistant, fil mag (B. Sc.) Bengt Johansson, an assistant master, is a doctoral student.

Note 5) see p. 3.

The separation of two knowledge producing activities

Fig 1

Törnebohm (1976) uses the notion of the inquiring system ($\hat{X}$ in figure 1), by which he means an open system in which investigations of a part of the real world (labelled Territory X in figure 1) are carried out. The arrow ($\hat{=}\!\!\rightarrow$, figure 1) refer to the hypotheses framed in $\hat{X}$ by researchers doing empirical research and is intended to map features of an object (X). There are other relations between $\hat{X}$ and X, which we intend to mention briefly. Primary information flows from X to $\hat{X}$ through various channels and the work done in $\hat{X}$ has a steering effect on its territory X.

The inquiring system ($\hat{X}$) may be the territory for empirical studies carried out by researchers in the theory of science. The last research-group constitutes another inquiring system (labelled $\hat{\hat{X}}$ in figure 1). Using this idea we can distinguish between two kinds of knowledge formation (as shown in figure 1). Let territory X be bodies in water: the problems which the researchers in $\hat{X}$ may faced with are why some bodies float at the air-water interface, why some bodies float around in the water and why other bodies sink to the bottom. The human creative activities in $\hat{X}$ now begin to produce knowledge about X. The results of the research process are concepts such as volume, weight, mass, density, force and pressure. Another type of result consists of models or theories, in which the created concepts are tied together

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5) We have reported elsewhere (Lybeck, 1977), that the platform of the theory of science in Göteborg (developed by professor Håkan Törnebohm) has been applied to questions in science education. In those studies we have contributed with our perspective of how concepts evolve in the Natural Sciences.

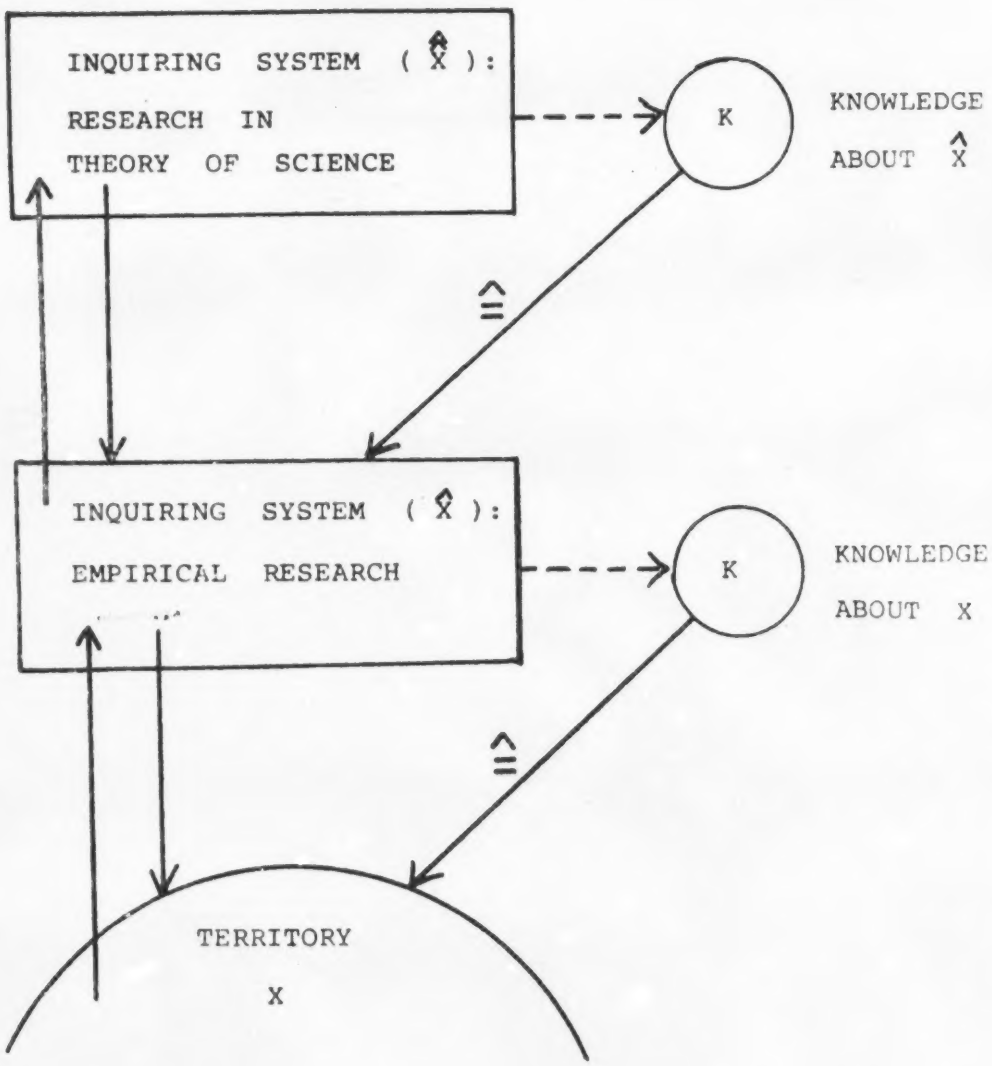
INQUIRING SYSTEM ($\hat{\hat{X}}$):
RESEARCH IN
THEORY OF SCIENCE
K
KNOWLEDGE
ABOUT $\hat{X}$
$\hat{\equiv}$
INQUIRING SYSTEM ($\hat{X}$):
EMPIRICAL RESEARCH
K
KNOWLEDGE
ABOUT X
$\hat{\equiv}$
TERRITORY
X

Figure 1.

in patterns. During the process of production of these results the researchers ($\hat{X}$) use concepts such as problem, instrument, hypothesis, experiment, data, model, theory, research group etc.

These concepts are themselves not the territory for research in $\hat{X}$. However, the researchers of the theory of science ($\hat{\hat{X}}$) are interested in these concepts as a part of their territory $\hat{X}$, namely how and why the researchers ($\hat{X}$) work with the last mentioned set of concepts in relation to the territory X.

In our example, the researchers $\hat{X}$ produce knowledge about some phenomena of a physical context, and the researchers of the theory of science ($\hat{\hat{X}}$) produce knowledge about some phenomena of the human creative context ($\hat{X}$) and the thought content of this human context. Like the theory of science, our discipline (science education) studies human contexts. Using the analogy, we wish to point out that, e.g., the theory of science of physics is not a branch of physics, and that physics education is not a branch of physics. Thus, science education has demarcation lines with other disciplines. It is of course a reasonable requirement that the researcher in, e.g., physics education has an intimate knowledge of physics. Our research territory is not the scientific disciplines itself but the thought content of the students in relation to them. And in fact, the content of the students' thoughts can neither be read in books nor said by teachers during lessons. As Marton (1977) has pointed out, we cannot simply apply the general descriptions of educational psychology of learning or thinking to content defined by disciplines such as Physics, Biology of Mathematics. Our territory has to be studied on its own conditions, and it cannot be deduced from general education or from any kind of 'crossing' of both of them.

Activities of the BMN-project

We have already stated that the main object of our studies is the students' thought content. Our study involves students in the natural science line (N-line) and in the technology

line (T-line) of the upper integrated secondary school. In the case of N-line students (grade 10, ages 16-17) we have concentrated on their physics education, because of the declining interest among students in this subject and the difficulties encountered by them in its study, especially when starting N-line courses[6].

We are currently examining the effects of the subject matter content on the students' concept formation in order to widen our understanding of the natural science concept formation and its relation to the mathematical concept formation. The pressure concept and related concepts were chosen.

During pilot studies we interviewed students individually on the problem of the Cartesian Diver, and found qualitative differences in the students' conception of this phenomenon. The students came from the N-line (grade 10), the social science line (So-line, grade 10) and from compulsory school (grade 7). They had been taught the concept of density and its quantitative definition three months before the study. In broad outline, our preliminary analysis gave three categories of thinking. In the first of these, the explanations are simple and absolute. From the point of view of common sense, the statement 'wood floats because it is light' appears to be an adequate explanation which in daily life is not questioned by people. The students base their explanations on one subsystem of the system. The view-point does not require them to think in terms of the relationships between subsystems. The point is that the statement 'it is heavy' is applicable and does not create misunderstanding. The second category implies in a certain sense a relativistic point of view. A stone sinks because 'it is heavier than water'. The student understands, as implied, that two equal volumes of the subsystems are compared. A feature of this category is that two subsystems are taken into account. The student sees a comparative relation between properties of the subsystems, e.g., their weight or volume. Some of the students tell us that

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6) The background has been reported by Lybeck (1977, p. 318).

the diver is sinking because its density is greater than the density of the water. Their conception of the phenomenon seems to be more differentiated, but they have difficulties in separating the concepts 'density' and 'mass', or the concepts 'density' and 'volume'. In a tentative third category, the formal definition of the density is known, but there are some uncertainties. The students run into problems when applying the density concept to phenomena in the daily world around them outside the realm of the school physics (Lybeck, Marton and Säljö, 1976).

A major problem that has emerged from our pilot study and from studies carried out in the classrooms is the following:

> Are the conceptual difficulties faced by the students in fact contextual ones, i.e. depending on the content, rather than structural ones, i.e. depending on general thought structures which in themselves are independent of the content?

Part of the content of a physics course is how knowledge is brought about and how new concepts are formed. To comprehend the meaning of a physical concept implies that the student knows how the concept might have been created. The students possess knowledge of 'primitive physics', which involves a view of how knowledge of physical phenomena is created. But the physical concepts of daily life are subjective and comparative, unlike the physical concepts in the science context, which are objective and quantitative. In contrast to the first set of concepts, the physical concepts (of science) can be combined with other physical concepts and (e.g. using formulas with Mathematics as an instrument) are bound in a conceptual structure. Concerning this transition from everyday context to a scientific context, our experience based on pilot recordings of lessons and laboratory activities leads us to suggest a central working hypothesis, namely:

> The gradual change from a daily perspective to a physical point of view is a core problem with respect to the conceptual difficulties the students meet in the teaching of physics.

The concept of proportionality is of central importance in the courses in mathematics and physics, especially in physics, it is an integrated theme in our N- and T-lines, grade 10. In our pilot studies, we found that several students had trouble in realizing that quantitatively described relationships in some sense are more adequate than less exact verbal descriptions. Why should I (the student) form the concept of average speed using proportionality between the distance travelled, d, and the time, t, when I already know what the speed is? The students do not lack quantitative explanations. The point is that their quantifications do not have an algebraic simplicity, as for example, a formula based on proportionality. The student possesses a working concept of speed. We can talk about a confrontation between the world of physics and the world of 'primitive physics'. In our view the teaching of physics ought to imply a reinterpretation using the students' old view as a starting point. The students should not have to learn the subject matter once more as this method may lead to parallell thought structures: one concept of speed for daily life and another for school physics.

We shall now discuss the main experimental activities of the BMN-project.

Methodological aspects and instrumentation

We have carried out two experimental studies of the students' comprehension of the physics concepts in the teaching of factual physics during the whole school year. At the lower level (1) of abstraction we have evolved an instrument for:

(1) the concepts of proportionality, density and velocity related to subject-matter content;

and at higher level (2) of abstraction an instrument for

(2) the students' conception and understanding of concepts such as problem, hypothesis, instrument, experiment, data, model and theory.

The instrument (2) relates to situations found in the classrooms and school laboratories. We want to know the students' comprehension of physics as a human created and developing

activity. We also want to find out students' attitudes to, and interest in, physics (and the natural sciences) and their attitudes to earlier and current physics teaching. With the instrument (1) we map the various forms of thought or forms of knowledge, in which the students comprehend certain types of subject matter and related concepts.

A third kind of experimental activity has had a direct influence on the students' way of working in physics. In collaboration with teachers, we have promoted concept formation on levels (1) and (2) by means of a problem-oriented teaching approach to physics, giving the students a good opportunity to effect their learning.

Our methods of data-generation involve mainly:

(a) individual interviews with the students from two experimental and two control classes (instruments (1) and (2)[7] were used); and

(b) continuous recordings of the factual teaching of physics during one school year in the two experimental classes.

For the recordings of the activities in classrooms and laboratories, the teachers and the students themselves generated the data of the factual teaching. During the educational process the researcher, too, was a part of the data-generating system. We recorded on two channels, one for the wireless microphone carried by the teacher, and the other for a larger microphone. During frontal teaching we asked elucidatory

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7) The instruments on level (1) are built upon tasks used in earlier studies by other researchers and on tasks with a direct connecting link to the factual teaching content in the classes. The interviews were carried out by the project head, who has continously followed and recorded the daily work of the teaching of physics in the experimental classes. In consultation with the experimental teachers, Marton, Säljö and the project head (the author) worked out the instrument on level (2). A major part of the interviews was carried out by Säljö and a minor part by the project head.

questions in order to improve the data-generating process with respect to the formation of concepts. During laboratory work or other group work, the researcher used the larger microphone and recorded the dialogues student-student or student-researcher. The teacher's activity was recorded at the same time. Our data in the longitudinal study demonstrates the development of the conceptual difficulties met by the student during the school-year.

We intend to use the results of the analysis of the interviews on levels (1) and (2), when making a final analysis of the teaching process.

Some tentative results

The analyses of our data is still in progress, but we are able to present some preliminary results here.

A Our studies of students' conception of proportionality based on tasks from studies done by other researchers, have forced us to introduce entirely different categories of description of the students' answers. We have used one thought dimension for the quantification process (the mathematical instrument used) and another thought dimension for the functional aspects of the tasks. The students can either quantify between the relevant variables, or they can quantify within one variable at the time, which means quite different strategies. (Johansson and Lybeck, 1978; Lybeck, 1978 b)

B We have been able to give descriptions of the qualitative differences in the students' spontaneous conceptions of the concepts of proportionality (point A), density, velocity and others from the outcomes of the individual interviews at the lower level (1) of abstraction.

C Likewise, descriptions of the qualitative differences in the students' spontaneous conceptions of the

knowledge producing process, have been made, based on the individual interviews at the higher level (2) of abstraction.

D We are able to give descriptions of the qualitative differences of the students' spontaneous conceptions of the concepts of levels (1) and (2) as formulated during the teaching process. Complementary concepts are on level (1) acceleration, force, frictional force, pressure, and on level (2) the concept of model.

E We are applying and intend to use the descriptions from points A, B, and C as instruments in our studies of the teaching process.

F Case studies of Archimedian Research Programmes using the conceptual framework of the theory of science in Göteborg have been carried out. Some of the proposed theoretical possible forms of knowledge have been recorded during problem oriented education, when the students are in the process of formulating their spontaneous forms of thought (Lybeck, Marton and Säljö, 1976). The study has pointed out aspects of the quantification process and the knowledge producing process.

G We use the theory of science in Göteborg in developing theoretical and empirical aspects of science education. Our research approach into science and mathematics education has recently been more extensively elaborated by Lybeck (1978 a).

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A P P E N D I X

ANALYSIS OF CONDITION FOR COOPERATION AND STRATEGIES FOR INNOVATION RELATED TO THE COGNITIVE DOMAIN

A paper worked out at the Joint ICMI/ICPE/CTS/ UNESCO/IDM-conference on 'Cooperation between Science Teachers and Mathematics Teachers', September 17-23, 1978, Institut für Didaktik der Mathematik, Bielefeld, FRG.

Working Group Members:

Bent Christiansen, Peter Fensham, Karl-Wolf Hoffmann, Leif Lybeck and Hans-Georg Steiner

ANALYSIS OF CONDITION FOR COOPERATION AND STRATEGIES FOR INNOVATION RELATED TO THE COGNITIVE DOMAIN

REPORT: COGNITIVE SUBGROUP OF GROUP E*

Several conditions relating the cognitive domain were identified. There were

1 The cognitive structure of the learner.
2 The cognitive structure of the teacher.
3 The differences between these two structures.
4 The continued co-existence of old or primitive structures despite new learning.

Cognitive structure means the receiving, processing and transmitting system of the individual at a certain moment.

Relation between Epistemological and Cognitive Structures

In science and mathematics and in the learning/teaching of these subject areas there is a constant interplay of two dimensions.

External expressions of views and theories, generally accepted knowledge and tools. ⟷ Internal representation of such public knowledge.

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* The cognitive subgroup of group E consisted of:

Bent Christiansen, Vice-president of ICMI, Professor Dr, Royal Danish School of Educational Studies, Copenhagen
Peter Fensham, Professor Dr, Faculty of Education, Monash University Victoria, Australia
Karl-Wolf Hoffmann, Dr, Projekt Autonomes Lernen, Universität Frankfurt, FRG
Leif Lybeck, Dr, Project head, Institute of Education, University of Göteborg, Sweden
Hans-Georg Steiner, Vice-president of ICMI, Professor Dr. Institut für Didaktik der Mathematik, Universität Bielefeld, FRG

In research they can be described as working patterns and paradigms.	⟷	Internalisation is also a process in which preexisting knowledge and tools are the operative factors.
We must recognize that all these are products of thought processes.		
These are "public" knowledge in the sence that they are accepted by different groups of persons and that by legitimation or sanctioning of behaviour of group members.		These are private views or knowledge, which can vary between members of the public group or new learners. An individual may hold more than one representation at a time.
Epistemological statements are examples of such public knowledge.		Cognitive structures are examples of such private knowledge

The public character of epistemological statements do not mean that they are fully articulated or comprehended in all their details by all members of the group. There are many examples where such tacit aspects of the epistemology of a science and mathematics are not understood by many of these teachers, e.g. "models" in chemistry, end "empirical subject" in mathematics.

The significance of the conditions for cooperation

The development of the learner's cognitive structure depends on

a the pre-knowledge (or existing cognitive structure).
b the subject content (e.g. differences between mathematics and the natural sciences).
c the teaching methods.
d the sequence of new knowledge presentation.

The cognitive structures of teachers determine but are not always accurately reflected in the way they talk during teaching.

Differences between these cognitive structures become barriers

to learning. Teachers' awareness of these differences is often inadequate and lessen their appreciation of the need for cooperation.

There is a need to assist teachers to become aware of

a the differences in the cognitive structures of students in their classes.

b their own cognitive structures, and especially their potential for continual development in relation to the public knowledge, and the fact that their structures are so dependent on their own education.

c the differences that exist between the cognitive structures of math and science teachers, and their relation to the similarities and differences in the two epistemologies.

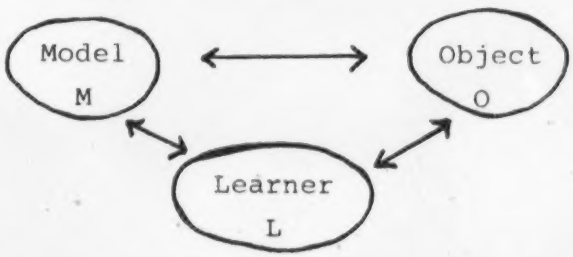
d the social aspects of change in cognitive structure.

The differences in the cognitive structure of students concerning concepts and processes in science and mathematics should not be seen as only a negative and depressing aspect of the tasks of science and mathematics teachers. There is a small but growing body of evidence that suggests that these cognitive structures are rich and fruitful bases for further learning provided they are recognized and the teaching is directed to them. Because these structures have developed as a result of earlier experiences in mathematics or science, they are particulary fruitful grounds for co-operative understanding between maths and science teachers. Furthermore, there is now evidence that the development of these cognitive structures have similarities with the evolution of scientific and mathematical knowledge. That is, they occur discontinuously through interactions that have strong social and psychological components. Teachers have tended to teach for, and expect, cognitive structures to change more smoothly by rational arguments.

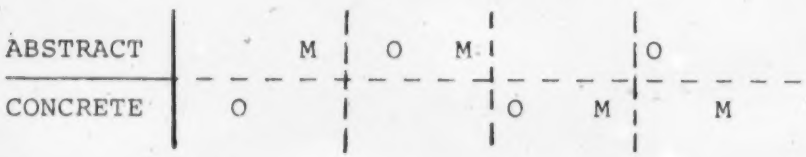
Thus, both groups of teachers have much to gain by recognizing and understanding these "learner" structures. There

is also evidence that children (and teachers) maintain primitive cognitive structures derived from early experiences of the natural and numerical world alongside the structures that formal studies in maths and science endeavour to establish. These also exert powerful influences that can impede learning unless they are recognized and adequately incorporated as part of the learning process. Again, a co-operative effort by maths and science teachers is needed to achieve such integration of these primitive and learned structures.

The cybernetic system



illustrates the interactive nature of the cognitive and epistemological structures in learning. There is a fluid movment in the learner between Object and Model in which both may be in an abstract mode or a concrete one as well as either of these two modes of awareness.



The fluidity of the learners' understanding with respect to (M) or (O) needs to be understood by teachers who are often characterised by more static positions about the (O) / (M) - relation as indicated by Revuz in his paper[1].

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1) Presented at this Joint ICMI/ICPE/CTS/UNESCO/IDM-conference. The proposed idea of the possible O/M-relationships ought to be elaborated, e.g. in Revuz' conceptual framework. (see Revuz, A. Mathematikunterricht und anwendbare Mathematik. Der matematische und naturwissenschaftliche Unterricht, 30. Jahrg., Heft 5, S 257-263, 15. Juli 1977)

This analysis of cognitive aspects that relate to co-operation lead to the following strategies for enhancing co-operation.

Strategies for co-operation

Three strategies are suggested:

I Booklets for teachers.
II Didactical analyses of the problem conditions for the use of teacher educators in pre- and in-service.
III Proposals regarding research to further I and II.

I. Our group regards booklets on conditions of co-operation of limited value for direct use by teachers. However, if case studies do exist (or can be written) of how teachers have recognized and dealt with such conditions, then these could indeed be used by the teachers in a school. These would be most useful if produced at an intra-national level.

II. Materials - case studies, verbatim reports of cognitive structures, their didactical significance, and the historical evolution of concepts - should be gathered and disseminated for use in teacher education. This can be international in scope.

III. There is a need for research that

(a) brings together, in both scholary and more public forms the existing state of our knowledge of the varieties of cognitive structures in relation to mathematics and related science concepts.

(b) reviews such as those of Cawthren and Rowell (Studies in Science Education, 5 (1978), 31-59) of the development of cognitive structure and its relation to the evolution of scientific knowledge should be widely disseminated in suitable form for the target audience of teacher educators and curriculum developers.

(c) extends our present understanding of the cognitive structures of the learners and teachers in mathematics and science education. The theoretical framework above is a starting point for such research and interviews based on this framework are very promising instruments for gathering the data.

(d) elaborates new theoretical frameworks for science and mathematics education that provide for co-operation. Examples are needed of how concepts have developed historically. These examples would be useful in teacher education in order to show how similar concepts - "system" in bilogy and physics - differ or are the same.

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59 Entwistle, Noel: Changing approaches to research into personality and learning. February 1977.

60 Härnqvist, Kjell: Primary Mental Abilities at collective and individual level. October 1977.

61 Härnqvist, Kjell: Enduring effects of schooling. - A neglected area in educational research. October 1977.

62 Härnqvist, Kjell: A note on the correlations between increments, cumulated attainment and a predictor. October 1977.

63 Gustafsson, Jan-Eric: The Rasch model for dichotomous items: Theory, applications and a computer program. December 1977.

64 Härnqvist, Kjell and Stahle, Gun: An ecological analysis of test score changes over time. December 1977.

65 Dahlgren, Lars Owe: Effects of university education on the conception of reality. May 1978.

66 Marton, Ference: Describing conceptions of the world around us. August 1978.

67 Gustafsson, Jan-Eric and Lindblad, Torsten: The Rasch model for dichotomous items: A solution of the conditional estimation problem for long tests and some thoughts about item screening procedures. June 1978.

68 Marklund, Ulla: Smoking in compulsory schools. Interviews and improvisations. September 1978.

69 Svensson, Lennart: Some notes on a methodological problem in the study of the relationship between thought and language. - Describing the thought content in terms of different conceptions of the same phenomenon. September 1978.

70 Härnqvist, Kjell and Gustafsson, Jan-Eric: International references to Swedish educational research: A citation study. October 1978.

71 Lybeck, Leif: A research approach into science education at Göteborg. October 1978.

72 Lybeck, Leif: Studies of mathematics in teaching of science in Göteborg. October 1978.